IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Vivian Alberts
App. No	:	10/568,227
Filed	:	May 17, 2006
For	:	METHOD FOR THE PREPARATION OF GROUP IB-IIIA-VIA QUATERNARY OR HIGHER ALLOY SEMICONDUCTOR FILMS
Examiner	:	Reames, Matthew L.
Art Unit	:	2895
Conf No.	:	6275

DECLARATION OF VIVIAN ALBERTS UNDER 37 C.F.R. § 1.132

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

I, Vivian Alberts, do hereby declare and say as follows:

1. I am currently a professor in the physics department at the University of Johannesburg in South Africa. I have been a professor at the University of Johannesburg for over 16 years. My work has focused on semiconductor physics and engineering, in particular the growth and characterization of polycrystalline ternary, quaternary and pentenary semiconductors such as $CuInSe_2$ and $Cu(In,Ga)Se_2$ and $Cu(In,Ga)(Se,S)_2$ Over the course of my career I have been an author or co-author of more than eighty (80) internationally reviewed and published technical papers concerning the growth and characterization of the above referred to materials and corresponding photovoltaic cells and modules. In addition, I am an inventor on various patents in the field of photovoltaic cells. I am also the inventor on the present patent Application. A list of some of my publications and patents is provided in the attached

curriculum vitae. I earned my bachelors of science degree from the University of Port Elizabeth in 1985. I earned my masters of science and PhD from the University of Port Elizabeth in 1990 and 1993, respectively.

2. I am the inventor of the invention claimed in U.S. Patent Application 10/568,227, which was field on May 17, 2006, and which is referred to herein as "the '227 Application." The '227 Application discloses, among other things, methods for producing group IB-IIIA-VIA quaternary or higher alloy semiconductor films.

3. I have read and understand the claims in the '227 patent application. I understand that the claims concern various methods for producing group IB-IIIA-VIA quaternary or higher alloy semiconductor films comprising various heat treating steps (Claim 1), a method for producing a group IB-IIIA-VIA pentenary alloy semiconductor film (claim 25), a method for producing a group IB-IIIA-VIA quaternary alloy semiconductor film comprising various heat treating steps (Claim 44), and a method for producing a group IB-IIIA-VIA quaternary alloy semiconductor film comprising various heat treating steps (Claim 82).

4. I have read and understand the rejections in the Office Action dated April 22, 2009. I understand that the Examiner has asserted: that Claims 1-7, 9-10, 15, 18, and 19 stand rejected under 35 U.S.C. § 102(b) as anticipated by the Background Section: that Claims 1-8, 13-21, 23-24, 26-31, 35-37, 40-41, 48, 44-46, 49-54, 61-66, 67, 70, 74, 78, 82, 84-86, 90-91 stand rejected under 35 U.S.C. § 102(b) as anticipated by Nagoya ("Role of incorporated sulfur into the surface of $Cu(InGa)Se_2$ thin-film absorber" 2001, hereinafter Nagoya); that Claims 9-12, 22, 31, 33, 34, 38-39, 47, 55-58, 71-75, 76, 79-80, and 87-88 stand rejected under 35 U.S.C. § 103 as unpatentable in view of Nagoya; and that. Claims 11-12, 43, 81, and 92-94 stand rejected under 35 U.S.C. § 103 as unpatentable in view of Nagoya and Kushiya ("The Role of $Cu(InGa)(SeS)_2$ Surface Layer on a Graded Band-Gap $Cu(InGa)Se_2$ Thin-Film Solar Cell Prepared by Two-Stage Method", hereinafter Kushiya).

5. I have reviewed the references cited by the Examiner, including the references in the background section and Nagoya, and Kushiya. The references in the background section and Nagoya, and Kushiya disclose a two stage process comprising a selenization step and a post-sulphurization step. The references in the background section and Nagoya, and Kushiya do not

teach a process with reaction conditions such that the reaction between the group VIA element and the metals of the mixture of the metal film is incomplete.

6. Attached to the Declaration is a flow chart illustrating the steps of the prior art processes as well as those of the present application. The prior art method depicted in the flow chart is usually referred to as "a two stage process". The reaction conditions of step (a), which comprise a one stage rapid ramping up of the temperature to the required level, are such that the elements of the substrate are fully selenized, i.e. the available binary metal selenides reacted, to form the two separate stable ternary alloys $CuInSe_2$ and $CuGaSe_2$. The metal selenides CuSe, InSe and GaSe are not present in any significant amount because they are consumed during the selenization reaction. The ternary alloys $CuInSe_2$ and $CuGaSe_2$ combine in step (b) to form a Ga-graded quaternary alloy $Cu(In,Ga)Se_2$, which, when subjected to the further heat treatment of step (c) in the presence of a source of S (referred to as post-sulphurization), yields a Ga-graded and Se-graded pentenary alloy $Cu(In,Ga)(Se,S)_2$. This is generally referred to in the prior art as a double-graded band gap alloy.

7. In embodiments described and claimed in the present application (illustrated in steps (ii) to (v) of said flow chart) , the substrate is treated with a selenide species (in step (ii) in the flow chart) under reaction conditions such that the selenization is incomplete and various binary alloys, including CuSe, InSe, Ga_2Se_3 and ternary alloys, including $CuInSe_2$ and $CuGaSe_2$, are formed. In one embodiment, a second selenization step (step (x) in the flow chart) forms a homogenous quaternary $Cu(In,Ga)Se_2$ alloy. In another embodiment, a first sulfurization step (step (iii) in the flow chart) forms a second film comprising sulpho-selenides including Cu(Se,S), In(Se,S), Ga(Se,S) together with the ternary chalcopyrite alloys $CuInSe_2$ and $CuGaSe_2$ formed in the first selenization step (step (ii) in the flow chart). A second sulphurization step (step (iv) in the flow chart) forms $CuIn(Se,S)_2$ and $CuGa(Se,S)_2$ alloys. A third sulphurization step (step (v) in the flow chart) forms a homogenous pentenary alloy $Cu(In,Ga)(Se,S)_2$.

8. I am not aware of any prior art that discloses method in which a homogenous quaternary alloy of $Cu(In,Ga)Se_2$ or a homogenous pentenary alloy of $Cu(In,Ga)Se,S)_2$ is formed.

9. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. I declare that these statements were made with the knowledge that willful false statements and the like so made

are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

Dated: 16 September 2009

By: _____
Vivian Alberts

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CURRICULUM VITAE

1. Biographical Sketch

Surname:	Alberts
Name:	Vivian
Place of Birth:	Eastern Cape
Date of Birth:	25/01/65
Marital Status:	Married
Citizenship:	South African
Employer:	University of Johannesburg, Department of Physics

2. Academic Qualifications

1985: B.Sc. – University of Port Elizabeth, South Africa
1986: B.Sc. Honours (Cum Laude) University of Port Elizabeth
1990: M.Sc. (Cum Laude) University of Port Elizabeth
1993: Ph.D. – University of Port Elizabeth, South Africa

3. Academic Achievements

1985: Recipient of CSIR merit bursary
1990: Recipient of Gencor S_2A_5 bronze medal for scientific achievement
1991: Recipient of National Study bursary: Top MSc thesis completed at a tertiary institution
1994: Awarded with National Research Foundation (NRF) rating
1995: Appointed as NRF principal grant holder (consortium of three universities)
1998: Recipient of merit award for top senior lecturer in the Faculty of Science, RAU
1998: Recipient International Federation of Societies for Electron Microscopy scholarship
1998: South African- German bilateral agreement: International funded research program
2000: Recipient of Volkswagen Foundation (Germany) research grant for a period of 3 years
2002: Recipient of Fulbright Scholarship
2000: Appointed by NRF principal grant holder of photovoltaic research groups in South Africa.
2003: Recipient of Innovation Fund Trust Grant: Department of Science and Technology
2006: Recipient of NRF B rating
2006: Recipient of the Academy of Science of South Africa Young Scientist Award
2007: Nominated for World Clean Energy Award

4. Academic Career and Appointments

1990 Appointed as Junior Lecturer in the Department of Physics, UPE
1993 Appointed as Lecturer in the Department of Physics, RAU
1995 Appointed as Senior Lecturer in the Department of Physics at RAU
1998 Appointed as Associated Professor in the Department of Physics at RAU
1999 Guest Professor at the University of Konstanz: Project leader in CIS PV group
2001 Full Professor and Chairman of the Department of Physics, UJ
2009 Full Professor of the Department of Physics at UJ / Managing Director PTIP (Pty)Ltd

5. International Research Visits

01.06 94- 07.19 94	University of Gent, University of Stuttgart, University of Konstanz
20.10.95- 30.01.96	Post-Doctoral studies, University of Stuttgart
01.02.95- 30.04.96	Post-Doctoral studies, University of Konstanz
20.05.98- 30.07.98	Guest professor, University of Konstanz
01.01.99- 01.04.00	Project leader in PV group, University of Konstanz
01.12.00- 01.01.01	Guest professor, University of Konstanz
04.06.01- 21.07.01	Guest professor, University of Konstanz
01.06.02- 05.07.02	Guest professor, University of Konstanz
07.07.02- 15.01.03	Fulbright Scholar, Institute of Energy Conversion, University of Delaware, USA
20.01.07- 15.12.07	Project Director: Johanna Solar Technology

6. Technical & Management Experience

More than 20 years of combined experience in the development and technical management of R&D laboratories and semi-commercial facilities, basic and applied research as well as process and product development related to **Semiconductor Physics & PV Technologies.**

- **Academic research** during MSc and PhD studies was related to the deposition of Si and GaAs by physical vapor phase deposition (PVD) and metal organic chemical vapor phase deposition (MOCVD). Novel processes and process parameters were developed to deposit epitaxial GaAs and AlGaAs thin films (nanometer scale) on Si substrates for device applications (e.g. LED's and hetero-junction devices). The semiconductor films were characterized using structural (e.g. SEM, TEM, XRD), optical (e.g. FTIR and low temperature PL) and electrical (e.g. Hall, four point probe and CV) techniques.
- Subsequent to my PhD studies, I took up a research position at the Department of Physics at the Rand Afrikaans University. I initiated two research projects in 1993 aimed at the development of processes and technologies for the fabrication of bulk Si and thin film $CuInSe_2$ photovoltaic (PV) cells and devices. The complete research program was developed with commercial-scale equipment which was acquired from redundant semiconductor facilities at the CSIR in Pretoria. Within a period of two years a comprehensive **semiconductor processing and characterization laboratory** was set up at the Department of Physics at RAU under my leadership and guidance. In 1994 the laboratory was fully operational and Si- based solar cells were produced with conversion efficiencies above 10%. The basic equipment used for Si research (e.g. diffusion furnaces, vacuum equipment and metallization) was modified in 1995 to produce the first laboratory-scale $CuInSe_2$ thin films and photovoltaic devices. All the fundamental processes (sputtering/diffusion/chemical) and the basic cell structures were developed on R&D level and the first 10% efficiency devices were produced in 1998. The absorber film material quality was improved by the addition of Ga and S to the basic $CuInSe_2$ lattice in the period from 1998 to 2002, which resulted in a consistent improvement in cell efficiency from 10 to 13% over the indicated period of time.
- In 2002/2003, a novel **deposition technology to produce homogeneous single-phase** chalcopyrite alloys $(Cu(In,Ga)(Se,S)_2)$ was developed, while being a Fulbright Scholar at the University of Delaware in the USA. The technology development over a period of almost 10 years and subsequent invention disclosure led to the formation of Photovoltaic Technology Intellectual Property (Pty) Ltd, a special vehicle IP company with its main objective to commercialize the PTIP technology locally and internationally.
- In 2003, a R12 million grant was received from the Innovation Fund Trust (Department of Science & Technology) to construct a **pilot production facility** at the Department of Physics at the RAU campus. I was chiefly responsible for defining and executing the technical and commercial milestones a s well as the day-to-day management of the technical program and operational responsibilities of the facility over a period of three years. Most of the critical technical milestones (material quality of individual steps and cell/module efficiencies) which were projected over a period of three years were achieved within one year after the pilot facility became fully operational in March 2005. The project was subsequently elected as one the most successful projects ever funded by the Innovation Trust Fund.
- As executive director of PTIP (Pty) Ltd, I have played an important role in the **technical and strategic management** of the company to date. The first international license was signed with a German company in August 2005 and the second with a South African based company in 2009. I was actively involved in the legal and commercial negotiations with potential investors and continue to advice the UJ council on any technical and commercial matters related to the core business of the company.
- During the **commercial development** phase in Germany, I was chiefly responsible for the transfer of the core technology from the UJ pilot plant to Johanna Solar Technology, training of all technical personnel at the UJ facility, negotiation of technical specifications of the core production equipment with equipment suppliers, specification of the raw materials (glass, target material, gases, chemicals etc), providing input values for the business model and general assistance during the application of debt financing and during the discussions with potential shareholders.
- During the project development phase of the South African company, Thin Film Solar Technologies (Pty) Ltd, I cooperated closely with German companies in order to design a fully automated 40MW production facility and associated production equipment. On the business development level, I provided key technical input parameters for the business model and interacted with potential investors and the European Investment Bank.

7. List of Technical Publications

[1] V. Alberts, J.H. Neethling and J.S. Vermaak
Nucleation and growth of germanium on Si (111)
Journal of Materials Science : Materials in Electronics 3 (1992) 240-243

[2] V. Alberts, J.H. Neethling and J.S. Vermaak
Structural characterization of gallium arsenide epitaxial layers grown on Si (001)
Materials Letters 13 (1992) 65-79

[3] V. Alberts, J.H. Neethling and J.S. Vermaak
Initial stages of MOVPE growth of GaAs on Si (001) and Si (111)
S. Afr. J. Science 88 (1992) 157-161

[4] V. Alberts
Influence of thermal annealing and the incorporation of AlGaAs/GaAs superlattices on the structural and optical properties of GaAs on Si
Semicond. Sci. Technol. 8 (1993) 2125-2134

[5] V. Alberts, J.H. Neethling and A.W.R. Leitch
Control of defects in the heteroepitaxial growth of GaAs on Si
S. Afr. J. Phys. 16 (1993) 82

[6]. V. Alberts
Influence of initial growth parameters on the structural and optical properties of GaAs on (001) Si
Journal of Crystal Growth 140 (1994) 299-307

[7] V. Alberts, J.H. Neethling and A.W.R. Leitch
Correlation between structural, optical and electrical properties of GaAs grown on (001) Si
J. Applied Phys. 75(11) (1994) 7258

[8] J.H. Neethling and V. Alberts
Multiple twinning in GaAs epitaxial layers grown on Si (001) and Si (111)
J. Applied Phys. 75(7) (1994) 3435

[9] V. Alberts
Initial stages of organometallic-vapour-phase epitaxial AlGaAs grown on (001) Si
Journal of Materials Science: Materials in Electronics 5 (1994) 291-299

[10] V. Alberts, J.H. Neethling and J.S. Vermaak
Nucleation and growth of gallium arsenide on silicon (111)
Journal of Materials Science 29(8) (1994) 2017-2024

[11] V. Alberts
Photoluminescence study of GaAs grown on (001) Si
Japanese Journal of Applied Physics 33(11) (1994) 6111-612012.

[12] A.W.R. Leitch, V. Alberts and J.H. Neethling
Electric properties of organometallic vapour phase epitaxial GaAs grown on Si
Materials Science Forum 143-147 (1994) 1611- 1616

[13] V. Alberts and R. Swanepoel
Structural analysis of $CuInSe_2$ thin films prepared by selenization of Cu-In films, Journal of Materials Science: Materials in Electronics, 7 (1996) 1933

[14] R. Herberholz, T. Walter, C. Müller, H.W. Schock, M. Saad and V. Alberts
Meyer-Neldel behaviour of deep level defects in $Cu(In,Ga)(Se,S)_2$ thin films, Appl. Phys. Lett. 69(19) (1996) 2888

[15] J.H. Schön, V. Alberts and E. Bucher
Sharp optical emissions from Cu-rich polycrystalline $CuInSe_2$ thin films
J. Appl. Phys. 81(6) (1997) 2799

[16] V. Alberts, S. Zweigart and H.W. Schock
Preparation of device quality $CuInSe_2$ by selenization of Se containing precursors in H_2Se atmosphere, Semiconductor Science and Technology 12 (1997) 217

[17] J.H. Schön, V. Alberts and E. Bucher
Structural and optical characterization of polycrystalline $CuInSe_2$
Thin Solid Films 301 (1997) 115

[18] V. Alberts, S. Zweigart, J.H. Schön, H.W. Schock and E. Bucher
Characterization of polycrystalline $Cu(In,Ga)Se_2$ thin films
Japanese J. Appl. Phys. 36(8) (1997) 108

[19] V. Alberts, R. Heberholz, T. Walter and H.W. Schock
Device Characteristics of In-rich $CuInSe_2$-based solar cells
J. Phys. D: Appl. Phys. 30(15) (1997) 2156

[20] V. Alberts and S. Zweigart
Vervaardiging en karakterisering van $CuInSe_2$/CdS/ZnO-dunlagiesonselle
SA Tydskrif vir Natuurwetenskap en Tegnologie 16 (1997) 122

[21] V. Alberts, M.J. Witcomb and R. Swanepoel
Material properties of $CuInSe_2$ prepared by H_2Se treatment of metallic alloys, J. Material Science 33 (1998) 2919

[22] V. Alberts
Solar cell devices based on polycrystalline $CuInSe_2$ thin films, South African Journal of Science 94 (1998) 341

[23] V. Alberts, J.H. Schön, M.J. Witcomb, E. Bucher, U. Rühle and H.W. Schock
Preparation of $Cu(In,Ga)Se_2$ polycrystalline thin films by two-stage selenization processes using H_2Se/Ar gas
J. Phys. D: Appl. Phys. 31(20) (1998) 2869

[24] V. Alberts, J.H. Schön and E. Bucher
Improved material properties of polycrystalline $CuInSe_2$ prepared by rapid thermal treatment of metallic alloys in H_2Se/Ar
J. Applied Physics 84(12) (1998) 6881- 6885

[25] V. Alberts, J.H. Schön and E. Bucher
Material properties and growth mechanism of $CuInSe_2$ prepared by H_2Se treatment of metallic alloys Journal of Materials Science: Materials in Electronics 10 (1999) 469

[26] J.H. Schön, V. Alberts and E. Bucher
Control and passivation of V_{Se} defect levels in H_2Se selenized $CuInSe_2$
Semiconductor Science and Technology 14 (1999) 657-659

[27] V. Alberts and M.L. Chenene
In-depth compositional uniformity of $CuInSe_2$ prepared by two-stage growth sequences
J.Phys. D: Applied Physics 32 (1999) 3093-3098

[28] V. Alberts, J. Bekker and M.J. Witcomb
The influence of H_2Se annealing procedure on the material quality of $CuInSe_2$ films
South African Journal of Science 95 (1999) 415-418

[29] V. Alberts, J. Bekker, M.J. Witcomb, J.H. Schön and E. Bucher
Control of V_{Se} defect levels in $CuInSe_2$ prepared by rapid thermal processing of metallic alloys
Thin Solid Films 361 (2000) 432-436

[30] V. Alberts, K.T. Hillie and C.M. Demanet
Atomic force microscopy imaging of polycrystalline $CuInSe_2$ thin films
Journal of Microscopy 197 (2000) 296-215

[31] V. Alberts and P. Molefe
Formation of $CuInSe_2$ thin films by H_2Se/Ar treatment of thermally evaporated metallic precursors from a single crucible
Japanese Journal Appl. Phys 39 (2000) 1650

[32] V. Alberts, M. Chenene, O. Schenker, E. Bucher
Preparation of $CuInSe_2$ thin films by rapid thermal processing of Se-containing precursors
Journal of Material Sciences: Materials in Electronics 11 (2000) 285-290

[33] V.Alberts, M. Klenk and E. Bucher
Material losses and compositional changes in two-step processed $CuInSe_2$ thin films
Japanese Journal of Appl. Physics 39 (2000) 5776

[34] V. Alberts, M. Klenk and E. Bucher
X-ray fluorescence investigation of Ga distribution in $Cu(In,Ga)Se_2$ thin films
Solar Energy Materials and Solar Cells 64 (2000) 371

[35] M. Klenk, V. Alberts and E. Bucher
Properties of flash evaporated chalcopyrite absorber films and solar cells
Thin Solid Films 387 (2000) 47

[36] J. Bekker, V. Alberts and M.J. Witcomb
Influence of selenization techniques on the reaction kinetics of chalcopyrite thin films
Thin Solid Films 387 (2000) 40

[37] M. Klenk, V. Alberts, O. Schenker and E. Bucher
Compositional analysis of two-step processed chalcopyrite thin films by X-ray fluorescence
Applied Surface Science 173 (2001) 62

[38] V. Alberts, M. Klenk and E. Bucher
Phase separation and compositional changes in two-stage processed chalcopyrite thin films
Thin Solid Films 387 (2001) 44

[39] J. Bekker, V. Alberts and M.J. Witcomb
Influence of selenization techniques on the reaction kinetics of chalcopyrite thin films
Thin Solid Film 387 (2001) 40

[40] M. Klenk, O. Schenker, V. Alberts and E. Bucher
Properties of flash evaporated chalcopyrite absorber films and solar cells
Thin Solid Films, 387 (2001) 47

[41] V. Alberts
Comparison of material properties of $CuInSe_2$ films prepared by reaction of metallic alloys to H_2Se/Ar and elemental Se vapour
Japanese Journal of Applied Physics 41 (2002) 518

[42] M. Klenk, O. Schenker, V. Alberts and E. Bucher
Preparation of device quality chalcopyrite thin films by thermal evaporation of compound materials
Semiconductor Science and Technology 17 (2002) 435

[43] V. Alberts and F.D. Dejene
Material properties of $CuIn(Se,S)_2$ thin films prepared by the thermal diffusion of sulfur into $CuInSe_2$
J. Phys D: Applied Physics 35 (2002) 2021

[44] V. Alberts
Preparation of $Cu(In,Ga)Se_2$ chalcopyrite thin films by H_2Se-free processes
South African Journal of Science 98 (2002) 604

[45] J. Bekker, V. Alberts, A.W.R. Leitch and J.R. Botha
Properties of $CuIn(Se,S)_2$ thin films prepared by two-step growth processes
Thin Solid Films 431-432 (2003) 116

[46] M. Klenk, O. Schenker, V. Alberts, U. Probst and E. Bucher
Properties of $CuGaSe_2$ absorber films prepared from stacked elemental layers by rapid thermal annealing and related processes
J. Phys D: Applied Physics 36 (2003) 2531

[47] F.D. Dejene and V. Alberts
Influence of GaSe deposition temperature on the structural properties and in-depth compositional features of two-step grown $Cu(In,Ga)Se_2$ thin films
J. Mater. Sci: Materials in Elec. 14 (2003) 89

[48] M.L. Chenene and V. Alberts
Structural and compositional properties of $Cu(In,Ga)Se_2$ thin films prepared by the thermal evaporation of compound materials
J. Phys. D: Applied Physics 36 (2003) 56

[49] V. Alberts and M.L. Chenene
Material properties of $Cu(In,Ga)Se_2$ thin films prepared by the reaction of thermally evaporated compound materials in H_2Se/Ar
Semiconductor Sci. Technol. 18 (2003) 870

[50] V. Alberts
Deposition of single-phase $Cu(In,Ga)Se_2$ thin films by a novel two-step growth process
Semiconductor Sci. Technol. 19 (2004) 65

[51] V. Alberts, J. Titus and R.W. Birkmire
Material and device properties of single-phase $Cu(In,Ga)(Se,S)_2$ alloys prepared by selenization/sulfurization of metallic alloys
Thin Solid Films 451-452c (2004) 207

[52] V. Alberts
Band gap engineering in polycrystalline $Cu(In,Ga)(Se,S)_2$ chalcopyrite thin films
Materials Science and Engineering B 107(2) (2004) 139

[53] F.B. Dejene and V. Alberts
Structural and optical properties of homogeneous $Cu(In,Ga)Se_2$ thin films prepared by thermal reaction of InSe/Cu/GaSe alloys with elemental Se vapour
J. Phys. D: Appl. Physics 37 (2004)

[54] C.J Sheppard, V. Alberts and W.J. Bekker
Deposition of $CuIn(Se,S)_2$ thin films by sulphurization of selenized Cu/In alloys
Physica Status Solidi (a), 1(9) (2004) 2234

[55] V. Alberts, O. Nemraoui, A.W.R. Leitch and J.R. Botha 2004
Structural and optical characterization of homogeneous monophasic $Cu(In,Ga)(Se,S)_2$ thin films
Physica Status Solidi (c) 1(9) (2004) 2311

[56] F.B. Dejene and V. Alberts
Preparation and structural properties of $CuIn(Se,S)_2$ thin films prepared by the thermal diffusion of sulphur into $CuInSe_2$
International Journal on Ambient Energy 26(2) (2004) 79

[57] J.R. Botha, S.A. Schumacher, Leitch A.W.R. and V. Alberts
Synthesis of single-phase $Cu(In,Ga)(Se,S)_2$ thin films by selenization and sulfurization of sputtered metallic alloys
Thin Solid Films 43 (2005) 116

[58] F.D. Dhlamini and V. Alberts
Synthesis of homogeneous pentenary chacopyrite alloys with a classical two-step growth technique
J. Physics and Chemistry of Solids 39 (2005) 1880

[59] V. Alberts
Structural and in-depth compositional features of homogeneous pentenary chalcopyrite alloys prepared with a reproducible deposition technology
J. Phys. D: Appl. Physics 39 (2005) 25

[60] S.A. Schumacher, J.R. Botha and V. Alberts
Photoluminescence study of potential fluctuations in thin layers of $Cu(In_{0.75}Ga_{0.25})(S_ySe_{1-y})_2$
J. Appl. Phys. 99 (2006) 063508-1

[61] C.J. Sheppard and V. Alberts
Deposition of single-phase $CuIn(Se_{1-y}S_y)_2$ thin films from the sulfurization of selenized CuIn alloys
J. Phys. D: Appl. Physics 39 (2006) 3760

[62] J.R. Botha, S.A. Schumacher, Leitch A.W.R. and V. Alberts
Homogeneity of single-phase $Cu(In,Ga)Se_2$ produced by selenization of metal precursors: An optical investigation
Thin Solid Films 511-512 (2006) 316

[63] M. Sugiyama, F.B. Dejene, A. Kinoshita, M. Fukaya, Y. Maru, H. Nakanishi, V. Alberts and S.F. Chichibu
Use of diethylselenide for the preparation of $Cu(In,Ga)Se_2$ films by selenization of precursors premixed with Se
Phyisca Status Solidi (c) 3(8) (2006) 2543

[64] F.B. Dejene, M. Sugiyama, H. Nakanishi and V. Alberts
Influence of the stacking order on the structural features of the Cu-In-Ga-Se precursors for formation of $Cu(In,Ga)Se_2$ thin films prepared by thermal reaction of InSe/Cu/GaSe to elemental Se vapour
Physica Status Solidi (c) 3(8) (2006) 2572

[65] M. Sugiyama, F.B. Dejene, A. Kinoshita, M. Fukaya, Y. Maru, H. Nakanishi, V. Alberts and S.F. Chichibu
Use of diethylselenide for the preparation of $Cu(In,Ga)Se_2$ films by selenization of precursors premixed with Se
Journal of Crystal Growth 294 (2006) 214

[66] C.J. Sheppard, V. Alberts and J.R. Botha
Structural and optical characterization of single-phase $CuIn(Se,S)_2$ thin films deposited using a two-step process
Phyisca Status Solidi (c) 5 (2007) 614

[67] V. Alberts
A comparison of the material and device properties of homogeneous and compositionally graded $Cu(In,Ga)(Se,S)_2$ chalcopyrite thin films
Semiconductor Science & Technology, 22 (2008) 585

[68] V Alberts
Band gap optimization in $Cu(In_{1-x}Ga_x)(Se_{1-y}S_y)_2$ by controlled Ga and S incorporation during reaction of Cu-(In,Ga) intermetallics in H_2Se and H_2Se
Thin Solid Films 517 (2009) 2115

[69] E. Macabebe, C.J. Sheppard, V. Alberts and E van Dyk
Effects of different selenization conditions on the device parameters of $CuIn(Se,S)_2$
Thin Solid Films 517 (2009) 2380

8. List of Technical Papers Published in International Proceedings

[70] J.H. Neethling and V. Alberts
Study of microtwins in GaAs epitaxial layers grown on Si
Proc. European Congress on Electron Microscopy (EUREM), 2, (1992) 151

[71] A.W.R. Leitch, V. Alberts and J.H. Neethling
Electrical properties of organometallic-vapour-phase epitaxial GaAs grown on Si substrates
Proc. 17th International Conference of Defects in Semiconductors (ICDS) Conference, (1993)

[72] V. Alberts and R. Swanepoel
Crystal Growth and characterization of $CuInSe_2$ thin films
Proc. 13th European Photovoltaic Solar Energy Conf., Nice (1995), 1933

[73] J.H. Schön, V. Alberts and E. Bucher
Characterization of $CuInSe_2$ thin films as function of composition
Proc. EuroSun, Freiburg (1996), 872

[74] V. Alberts, S. Zweigart, U. Rühle and H.W. Schock
Material properties of $CuInSe_2$ thin films prepared by H_2Se treatment of Se containing precursors
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[75] V. Alberts, R. Herberholtz, T. Walter and H.W. Schock
Growth and characterization of In-rich $CuInSe_2$ materials
Proc.14th European Photovoltaic Solar Energy Conf., Barcelona (1997) 2117-2120

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Proc.14th European Photovoltaic Solar Energy Conf., Barcelona (1997) 1311-1314

[77] V. Alberts, J.H. Schön, O. Schenker and E. Bucher
Material properties and growth kinetics of $CuInSe_2$ and its alloys by various selenization processes
Proc. 2nd World Conference on Photovoltaic Solar Energy , Vienna (1998) 533

[78] V. Alberts, S. Zweigart, J.H. Schön, E. Bucher and H.W. Schock
Material properties of $Cu(In,Ga)Se_2$ thin films prepared by low cost, fast processing techniques"
Proc. 2nd World Conference on Photovoltaic Solar Energy , Vienna (1998) 1137

[79] M.J. Witcomb and V. Alberts
Transmission electron microscopy study of thin film $CuInSe_2$ photovoltaic materials
Proc. 14th International Congress on electron microscopy, Mexico (1998) 2, 353

[80] V. Alberts, M. Klenk and E. Bucher
Compositional depth profiling of $Cu(In,Ga)Se_2$ thin films prepared by different growth techniques
Proc. 16th European Photovoltaic Solar Energy Conf., Glasgow (2000)

[81] M. Klenk, O. Schenker, V. Alberts and E. Bucher
X-ray fluorescence investigation of the material loss from chalcopyrite absorbers prepared by two-step processes
Proc. 16th European Photovoltaic Solar Energy Conf., Glasgow (2000)

[82] M.J. Witcomb and V. Alberts
Microscopy study of polycrystalline chalcopyrite thin films
Proc. 15th International Congress on electron microscopy (2000), California, 412

[83] V. Alberts and M.J. Witcomb
Structural analysis of chalcopyrite thin films produced by selenization of metallic alloys
Proceedings of the 16th International Congress on electron microscopy, Durban (2002) 861

[84] V. Alberts
Deposition of single-phase chalcopyrite thin films by a novel two-stage growth process
Proc. of the 19th European Photovoltaic Solar Energy Conference, 7-11 June 2004, Paris, France, pp 1824 – 1827

[85] C.J. Sheppard and V. Alberts
Deposition of single-phase $CuIn(Se,S)_2$ thin films from the sulfurization of selenized CuIn alloys
Proc. 18th European Photovoltaic Solar Energy Conf., Barcelona, Spain, 2005

[86] C.J. Sheppard and V. Alberts
$CuInGa(Se,S)2$ and $CuIn(Se,S)_2$ –based devices manufactured from homogeneous single-phase absorber films
Proc. 21th European Photovoltaic Solar Energy Conf., Dresden, Germany, 4-8 September 2006, pp 1958

[87] V. Alberts, E. Scholtz, C. Chiteme, F.D. Dhlamini, C.J. Sheppard, P. Molefe, M. Chinene
CIGSSe pilot facility results: Dramatic demonstration of commercial success
Invited Talk: Proc. 21th E uropean Photovoltaic Solar Energy Conf., Dresden, Germany, 4-8 September 2006, pp 1810

[88] V Alberts
Band gap optimization in $Cu(In_{1-x}Ga_x)(Se_{1-y}S_y)_2$ by controlled Ga and S incorporation during reaction of Cu-(In,Ga) intermetallics in H_2Se and H_2Se
Invited Talk: European Materials Research Society, Strassbourg, France (2008)

[89] CJ Sheppard, EQ Macabebe, EE van Dyk, V Alberts
Electrical characterization of $CuIn(Se,S)_2$ based devices manufactured using a novel two-step process.
23 Photovoltaics Solar Energy Conference, Valencia, Spain, 2008

9. List of Patents

[1] Inventor: V Alberts
Title: *Method for the preparation of Group IB-IIIA-VIA Quartemary or Higher Alloy Semiconductor Films (Process Patent)*
Publication Date: 24 February 2005, PCT WO 2005/017978 A2

[2] Inventor: V. Alberts
Title: *Group I-IIA-VI Quartemary or Higher Alloy Semiconductor Films (Product Patent)*
Publication Date: 24 February 2005, PCT WO 2005/017979 A2

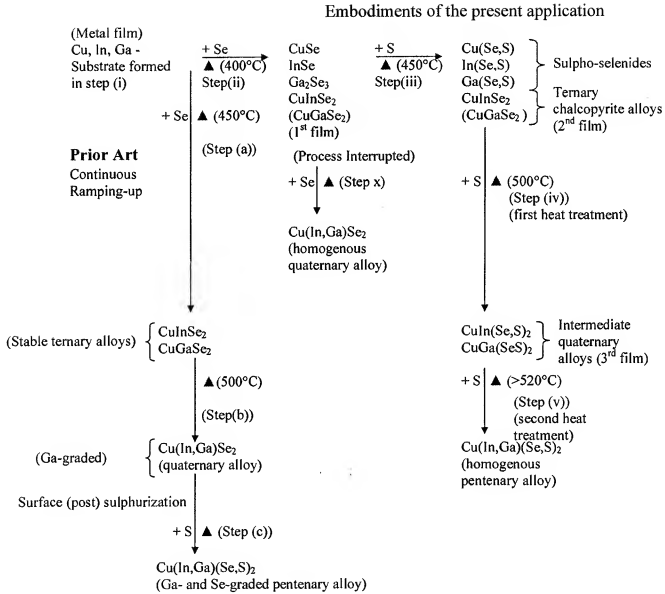
[3] Inventors: C. Köckert, U. Willkommen, V. Alberts and H-C Hecht.
Title: "Verfahren zur Temperaturführung in einen Diffusionofen"
Publication Date: 12 July 2007, HA 988 DE

[4] Inventors: C. Köckert, H-C Hecht, S. Gregor, U. Willkommen and V. Alberts
Title: "Diffusionofen und Verfahren zur Temperaturführung"
Publication Date: 25 October 2007, HA 989 DE

[5] Inventors: U. Willkommen, V. Alberts, C. Klenke, T. Bock,
Title: In-line Diffusion Furnace for Johanna Technology
Publication Date: 17 April 2008, HA 1010 DE

10. Additional Scientific Contributions

More than 50 technical papers were presented at national conferences (SAIP & MSSA) over the past 20 years. Eighteen post graduate students completed their MSc and PhD studies in the field of PV under my supervision in the period between 1994 and 2008. Invited by numerous international journals to act as a referee for scientific papers. Chairman and/or member of the organizing committees of nati onal and international conferences.


Embodiments of the present application
(Metal film)
Cu, In, Ga -
Substrate formed
in step (i)
+ Se
▲ (400°C)
Step(ii)
+ Se ▲ (450°C)
(Step (a))
Prior Art
Continuous
Ramping-up
CuSe
InSe
Ga2Se3
CuInSe2
(CuGaSe2)
(1st film)
+ S
▲ (450°C)
Step(iii)
(Process Interrupted)
+ Se ▲ (Step x)
Cu(In,Ga)Se2
(homogenous
quaternary alloy)
Cu(Se,S)
In(Se,S)
Ga(Se,S)
CuInSe2
(CuGaSe2)
Sulpho-selenides
Ternary
chalcopyrite alloys
(2nd film)
+ S ▲ (500°C)
(Step (iv))
(first heat treatment)
(Stable ternary alloys)
CuInSe2
CuGaSe2
▲(500°C)
(Step(b))
(Ga-graded)
Cu(In,Ga)Se2
(quaternary alloy)
Surface (post) sulphurization
+ S ▲ (Step (c))
Cu(In,Ga)(Se,S)2
(Ga- and Se-graded pentenary alloy)
CuIn(Se,S)2
CuGa(SeS)2
Intermediate
quaternary
alloys (3rd film)
+ S ▲ (>520°C)
(Step (v))
(second heat
treatment)
Cu(In,Ga)(Se,S)2
(homogenous
pentenary alloy)